Northwest Atlantic Fisheries Organization

Serial No. N6569 **NAFO SCR Doc. 16/26 Rev.**

SCIENTIFIC COUNCIL MEETING – JUNE 2016

An assessment of NAFO roughhead grenadier Subarea 2 and 3 stock.

by

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ABSTRACT

The aim of this paper is to present the status of NAFO roughhead grenadier Subarea 2 and 3 stock. Different assessment methods have been applied based on the available data: XSA, ASPIC and a qualitative assessment based on survey and fishery information. The fit of the data to the XSA and ASPIC has been very poor mainly due to lack of contrast and conflicting information from the surveys data. Therefore the results are not considered representative of the stock situation.

There are not available surveys indices covering the total distribution, in depth and area, of this stock. Biomass indices from the surveys with depth coverage till 1400 meters are considered as the best survey information available to monitor trends in resource status because they cover the depth distribution of roughhead grenadier fairly well.

Surveys biomass indices present a general increasing trend in the period 1995-2004. In the period 2005-2012 all available indices show a clear downward trend except the Canadian Fall (2J+3K) index. In the most recent period (2013-2015) the information of the different indices is contradictory, the Canadian 2J3K and the EU 3L show an increase while EU-FC and EU 3NO continue to decline. With regard to fishing mortality, the trends of the different estimations of F were very similar. F presents a decreasing trend since 1998 till 2006 and since then is more or less stable at very low levels. The recruitment indices analysed (Surveys length and age distributions) show at least three good cohorts: 1993, 2001 and 2012 year classes. To confirm the strength of the last good year class (2012) it would need to have more information about it.

INTRODUCTION

Roughhead grenadier (*Macrourus berglax* Lacépède, 1802) is an abundant widespread fish species in the North Atlantic, usually found both on the shelf and on the continental slope (Scott and Scott, 1988; Savvatimsky, 1994). It is predominant at depths ranging from 800 to 1,500 m (Murua and De Cárdenas, 2005), although they may inhabit depths between 200 and 2,000 m (Snelgrove and Haedrich, 1985; Murua and De Cárdenas, 2005). It has, however, been rarely found in depths down to 2,700 m (Wheeler, 1969). This species is commonly found in temperatures ranging from about -0.5 to 5.4 ºC (Atkinson and Power, MS 1987).

The fishery for Roughhead grenadier is unregulated and it is taken as by catch in the Greenland halibut (*Reinhardtius hippoglossoides*) fishery (Gonzalez-Costas, 2012), mainly in NRA Divisions 3LMN. Most Roughhead grenadier catches are taken by trawl and the only management regulation applicable to

Roughhead grenadier in the NRA is a general groundfish regulation requiring the use of a minimum 130 mm mesh size.

The knowledge on the biology and population dynamics of Macrouridae is sparse (Gordon, 1979; Middleton & Musick, 1986; Atkinson, 1995; D'Onghia et al., 2000). In particular, little has been published on the biology, growth and reproduction of Roughhead grenadier on both sides of the North Atlantic. Moreover, the age structure and growth of the Roughhead grenadier, based on otolith readings of specimens captured in the North-West Atlantic, were estimated by Murua and González (2006).

The stock structure of this species in the North Atlantic remains unclear because there is little information on the number of different populations that may exist and their relationship. In the Northwest Atlantic Fisheries Organization (NAFO) area, Roughhead grenadier is distributed throughout Subareas 0 to 3. However, for assessment purposes, NAFO Scientific Council considers the population of Subareas 2 and 3 as a single stock (NAFO, 2005). Although the knowledge available on the biology of this deepwater species is not extensive, over the last few years, more biological information as well as research survey indices have been analysed (Murua et al., 2005; Gonzalez-Costas,2013). The aim of this paper is to present the status of this stock based on different assessments models using all the available information.

Data

Catches

In 1998 Power and Maddock Parsons revised the Roughhead grenadier catch statistics since 1987 for assessment purpose. Before 1987 there is not roughhead grenadier catch information available in the NAFO STATLANT data base. This could not mean that there should not have catches of this species before 1987. The reason for this doubt it is that before 1987 roundnose grenadier was the only name that appeared in the STATLANT reporting forms. Table 1 and Figure 1 show the 1987-2015 NAFO Subarea 2 and 3 catches for this species. Since 1987, most of the Roughhead grenadier catches were taken as by-catch in the Greenland halibut fishery in Div. 3LMN by Spain, Portugal and Russia fleets. Catches increased sharply from 1989 (333 tons) to 1992 (6725 tons); since then until 1997 total catches have been around 4000 t. In 1998 and 1999 catches increased and were near the level of 7000 tons. Since then, catches decreased to 3000–4000 tons in the period 2001–2004 and to 1000 tons in 2007. In the period 2007-2012, annual catches have been around 1000 tonnes and in the last three years about or less than 500 tonnes.

Catches Length Distributions

Roughhead length frequencies from the Spanish, Portuguese and Russian trawl in Div. 3LMNO are available from Gonzalez-Costas *et al.* (2016), Vargas *et al.* (2016) and Fomin K. and M.Pochtar (2016) respectively. Table 2 presents the availability of the length distribution in the series. Due to the growth differences between sex, length and age data have been analysed by sex. The Spanish and Portuguese lengths frequencies are measured as pre anal fin length (AFL), while the Russian ones as total lengths. The roughhead length compositions from the Russian catches have been converted to AFL using the total length / AFL relationship presented by Murua and Motos (1997). Figure 2 shows the length distribution by year and country for the period 2013-2015. The Spanish and Russian length distributions are very similar and different from the Portuguese ones. The Portuguese fleet catch individuals smaller than the Spanish and Russian fleets. This pattern is similar to the observed in the period 2010-2012. Total catches length distributions for the stock were estimated raised the join Spanish, Portuguese and Russian catches length distribution to the total catches. Table 3 and Figure 3 present the total catches length distribution for the roughhead grenadier Subarea 2+3 stock. Figure 4 presents the sex ratio by length of the catches length distributions for 2013-2015. The proportion of males in the catches after 18 cm decreases progressively as length increases and it is very difficult found males more than 28 cm. This patter is the same founded in previously studies (Murua and Gonzalez, 2007).

Catch-at-Age

Ageing was based on otoliths from specimens caught by Spanish commercial fleet and UE scientific surveys in NAFO Divisions 3LMN. The total catch-at-age numbers presented by González-Costas (2013) have been

updated with the 2013-2015 length data applying the ALKs presented in the Spanish Research Reports (Table 4 and Figure 3). Table 2 presents the data available to create the catch-at-age matrix. The associated mean weights and mean length by age are presented in Table 4. In the period 2013-2015, most of annual catches are composed between ages 4 and 12, with a mode at age 5-6. This mode is quite similar to the period 2010-2012 and was slightly different in the years before: in 2009 was 8 and 7 in 2008.

Research Survey Data

Biomass indices for the roughhead grenadier Subareas 2 and 3 stock are available from various research surveys, with different depth and area coverage (Table 5). None of them cover the total area and depth distribution of this stock.

Canadian deepwater survey: Canada conducted deepwater bottom trawl surveys (750 – 1500 m.) in 1991, 1994 and in 1995 in Divisions 3 KLMN. The results of those surveys were reported by Atkinson *et al.* (1994) and Bowering *et al.* (1995), and are presented in Table 6. Most part of the biomass was taken in Div. 3L and 3M at depth more than 700 m., which confirms that the stock in those Divisions is distributed beyond the depths covered by the spring surveys in those Divisions.

Canadian fall survey: Stratified random bottom trawl surveys have been conducted in Div. 2GHJ and 3KL in fall since 1978, usually in October-November. Since 1990 the survey also covered Div. 3MNO. Until 1995 an Engel trawl was used, changed since then to a Campelen 1800 gear. At the beginning of the surveys depth coverage was up to 1000 m in Div. 2GHJ and 3K and to 730 m in Div. 3LNO, it was extended to 1463 m after 1995. A description of those surveys is in McCallum and Walsh (1996) and Power and Parsons (1998). Operational difficulties in some years lead to incomplete coverage (depth and surface) of the survey (Brodie 2005; Healey and Dwyer, 2005, Healy 2009 and Healy *et al* 2012). The estimates from 1995 onwards are not directly comparable with the previous time series due to the change in the survey gear. Taking into account the incomplete coverage of some strata in divisions 2GH and 3LMNO only the index of divisions 2J and 3K from both series (Engel and Campelen) are comparable. It was determined that the coverage deficiencies within Divs. 2J3K were such that the 2008 index from Divs. 2J3K could not be considered comparable to that of previous years (Healey and Mahé, 2009). The roughhead biomass index (DIV. 2J3K MWPT) from this survey since 1978 are presented in Table 6 and Figure 5. The Engel series (1978-1994) present a clear decreasing trend since 1978 till 1994. The Campelen series shows an opposite trend, the index increase from 1995 till 2015. Figure 6 presents the 2J3K Canadian fall survey length and age distributions. The transformations of the lengths in ages were made applying the EU Flemish Cap survey ALK to the length indices. Although the tracking of cohorts in time is noisy, it can be observed three good cohorts: 1993, 2001 and 2012 year classes. To confirm the strength of the 2012 year class it would need to have more information about it.

Canadian spring survey: Stratified random bottom trawl surveys have been conducted in Div. 3L, 3N and 3O in spring since 1978. A description of those surveys is found in McCallum and Walsh (1996). Until 1996 an Engel trawl was used, changed to a Campelen 1800 since then. The depth range of the surveys is up to 731 metres. Roughhead grenadier information is available from this survey since 1991. But again in this case a direct comparison of the biomass levels through the whole time series is not possible due to the change in the survey gear in 1995. Operational difficulties in 2006 and 2015 resulted in incomplete coverage of the survey in Div. NO and the estimates for these years are not directly comparable with the time series (Rideout, 2016). Table 6 present the estimated Roughhead grenadier biomass from this survey and Figure 7 shows the biomass index since 1996 till 2015. From 1996 to 2004, the biomass level was more or less stable. In 2005 and 2007, it had a big increase and from 2008 to 2012 it was more or less stable at similar level than the period 1996-2004. The last three years it presents a decreasing trend. Biomass estimates from the spring survey series are considerably lower than the ones obtained in the autumn series, as the spring surveys cover only the southern divisions and the shallower depths, where according to other information this species is less abundant.

Rideout (2016) presented the spatial pattern of catches in the Canadian autumn and spring surveys for the period 1998-2015 in order to summarize the distribution of NAFO stocks including roughhead grenadier in

SA2+3. Although the depth coverage of the surveys are different, it can be observed that the largest catches for both surveys are made throughout the deeper part of the slope every year.

Flemish Cap (EU Spain and Portugal) 3M survey: EU- Spain and Portugal conduct a stratified bottom trawl survey in Div. 3M since 1988, up to depths of 730. The survey procedure is described in Vázquez *et al.* (2013). Since 1991, the survey was made with the R/V Cornide de Saavedra. In 2003 this vessel was replaced by the R/V Vizconde de Eza. The former series of Cornide de Saavedra was transformed to the new R/V Vizconde de Eza units following the method presented by Gonzalez Troncoso and Casas (2005). In 2004 the depth coverage of this survey has been extended to 1463 m. The Roughhead grenadier biomass indices from this survey series (Alpoim and Gonzalez-Troncoso, 2016) until 730 m from 1991 to 2015 and until 1400 m from 2004 to 2015 are presented in Table 6 and Figure 8. The 730 m. biomass indices present a peak in 1993. From then until 2002, the biomass index was more or less stable at values in between 1 and 2 kg per tow. From 2002 onwards, the biomass index shows an increasing trend, reaching a historical maximum in 2006. Since 2007 the indices have been variable with a general decreased trend, reaching their historical minimum in 2014. The 2015 index value is very similar to the 2014. The 1400 indices show a clear decreased trend since the beginning of the series with its minimum in 2015. Figure 9 presents the length and age distributions of the EU Flemish Cap survey from 2004 to 2015 until 1400 meters depth. Although the tracking of cohorts in time is not clear, it can be observed a a strong 2001 year class. Since them there are not good recruitment signals in this index.

EU-Spanish 3NO Survey: EU-Spain conduct a stratified random spring bottom trawl survey in the NAFO Regulatory Area Division 3NO since 1995. In 2001 the C/V Playa de Menduíña with a net trawl type Pedreira was replaced by the R/V Vizconde de Eza, using a trawl net type Campelen. The transformed entire series of mean catches, biomass and length distributions for Roughhead grenadier were presented by Gonzalez-Troncoso et al. (2016) since 1997, year in which the survey was extended to the 1400 meters depth. The roughhead grenadier biomass index from this survey series is presented in Table 6 and Figure 10. From 1997 to 2002 the biomass index of this survey was quite stable. Since then it has increased and in the period 2004-2006 reached the maximum level. In 2007 decreased and since then until 2012 was more or less stable at similar 2003 level. In the period 2012-2014 decreases and in 2015 shows a small increase. The length and age distributions of the survey series (Figure 11) showed three good cohorts similar to the Canadian 2J3K index although strong cohorts are not same, normally in the EU 3NO index are observed one year later. This could be due to the survey season, at the end of the year in the Canadian autumn survey and in the middle of the year for UE-Spanish 3NO survey. To confirm the strength of the last good year class it would need to have more information about it.

EU-Spanish 3L Survey (Flemish pass): The EU-Spanish surveys in Div. 3L of NAFO Regulatory Area (Flemish Pass) was initiated by Spain in 2003. The Research vessel "Vizconde de Eza" has carried out the entire surveys series following the same procedures and using the same bottom trawl gear Campelen 1800. To know more details about the technical specifications of the surveys, see Román *et al.*, 2009. In 2003, the survey was carried out in spring (June) and it did not cover all strata adequately (69% of the total area prospected in 2006-2012). In 2004, the survey was carried out in August, for a period of nine days, and it covered only the 96%. In 2005, it was not possible to perform the survey due to problems with the winch of the ship; and in 2006, for the first time, an adequate prospecting survey was conducted in Division 3L with over 100 valid hauls. Due to these coverage and technical problems only the series since 2006 is analysed. The Roughhead grenadier biomass index from this survey series were presented by Roman *et al.* (2016) and show in Table 6 and Figure 10. From 2006 to 2008 the biomass index was stable and since them presents a clear decreasing trend, reaching the time series minimum in 2012. In the period 2013-2015 the index increased to levels similar to the period 2006-2008.

There are not available surveys indices covering the total distribution, in depth and area, of this stock. Canadian Divisions 2J and 3K fall index and the Spanish research survey in Divisions 3NO have been considered as the best information available in order to monitor trends in resource status (NAFO 2010) because they cover depths down to 1,500 metres and, hence, cover the depth distribution of Roughhead grenadier fairly well (Murua and De Cardenas, 2005). Now there are available more surveys series cover depths down to 1,500 metres. Figure 12 presents the relative mean weight per tow for all the series available

cover down to 1,500 meters depth. It can be seen a increasing period since 1995 till 2004-2008 for all available indices and since them all the indices show a decreasing trend until 2012, except the Canadian fall 2J+3K index. In the most recent period (2013-2015) the information of the different indices is contradictory, the Canadian 2J3K and the EU 3L show an increase while EU-FC and EU 3NO continue to decline.

ASSESSMENT METHODS

Three different assessment methods have been applied to the available data described above: Extended Survivors Analysis (XSA, Shepherd, 1999; Darby and Flatman, 1994), a Stock-Production Model Incorporating Covariates (ASPIC, Prager 1994 and 2004) and a qualitative assessment based on survey and fishery information.

Extended Survivors Analysis (XSA)

Extended Survivors Analysis was applied to the commercial catch-at-age data for Roughhead grenadier in NAFO Subarea 2 and 3 from 1992-2015 to assess the current status of the stock. The XSA model formulation was based on the analysis made by Gonzalez-Costas and Murua (2007) and Gonzalez-Costas (2013) with the following configuration:

- Catch data for 24 years (1992-2015). Ages 3 to 17+ (Table 4).
- Tapered time weighting not applied.
- Catchability independent of stock size for all ages.
- Catchability independent of age for ages >= 15
- Survivor estimates shrunk towards the mean F of the final 2 years or the 2 oldest ages.
- S.E. of the mean to which the estimates are shrunk = 1.000
- estimates derived from each fleet = 0.300
- Prior weighting not applied.
- Plus group was established 17+ and Fbar was defined as the mean F for ages between 6 and 13 years.
- Natural mortality (M) at age was assumed to be constant and was set at 0.1 for all years.

The reason for selecting this value for M is that the Roughhead grenadier is a long-lived species that inhabits a stable deep-sea ecosystem. This value has been applied in the assessment of some stocks of Roundnose grenadier with similar biology and inhabiting similar ecosystems (ICES, 2006).

Based on this model formulation, it was update the 2013 run 3 (Gonzalez-Costas, 2013) that it has as tuning information the following surveys indices: Canadian Fall 2J+3K (1995-2015), EU-Spanish 3NO (1997-2015) and EU Flemish Cap till 700 m (1994-2003) and till 1400 m (2004-2015). These tuning series were created applying the UE-Flemish Cap ALK to the MNPT length information of each series.

The Extended Survivors Analysis (XSA) model configuration previous described converged after more than 200 iterations. This high iterations number needed to reach the convergence is a signal of the problems to fit the model with the available data. These problems can be due to different factors like conflicting and area incomplete survey coverage. Difficulties to track the cohorts, age reading problems, etc.

Catchability is the link between survey catches and population abundance as estimated from the catch-at-age data and the model assumes that surveys catchabilities-at-age are constant with respect to time. The surveys Standard Error (SE) of the log catchability for this run are presented in Figure 13. Values higher than 0.5 can be interpreted as fit problems. The Canadian 2J+3K and the EU 3NO surveys present quite good SE values for all ages and both EU Flemish Cap series present problems for younger and older ages. The log catchability residuals for each survey by year (Figure 14) show that there are time trends in all the residual series since 2007 till now. These trends are different depending on the series. The EU Flemish Cap indices till 1400 m, present a clear decreasing trend in the residuals. These trends are signals that the constant catchability assumption is not met.

Total biomass, mean F between ages 6 to 13 (Fbar), recruitment (Age 3) results and catches are plotted in Figure 15 and presented in Table 7. Model results indicated that the stock biomass has an increase trend till 2007 and since then present's fluctuations around the maximum of 115000 tonnes. Fishing mortality has declined since 1998 till 2007 and from then was quite stable a low level. The current level of F is much smaller than the value assumed for the natural mortality. The recruitment presents a decreasing trend since 1998 till 2009 where reached its minimum and in since then till 2015 show a clear increasing trend. The results, at least quantitatively, are considered to be uncertain due to a number of factors that might influence the quality of the outcome, such as the high number of iterations required in all runs to reach convergence, the conflicting trend in the tuning indices, the low Fishing mortality estimated in the last years compare with the assumed the natural mortality level, etc.

Stock-Production Model Incorporating Covariates (ASPIC)

A non-equilibrium surplus production model incorporating covariates (ASPIC) (Prager, 1994) was applied to nominal catch for roughhead grenadier in NAFO Subarea 2 and 3 from 1987-2015 and survey biomass indices. The logistic (Schaefer 1954 and 1957) production model used assumes logistic population growth. Initial biomass (expressed as the ratio: B1/K), K, MSY, and catchability coefficients for each biomass index (qi) were estimated using non-linear least squares of survey residuals.

Based on the analysis made by Gonzalez-Costas (2013) it was decided to update the 2013 ASPIC run2 (Table 8) using the ASPIC version 5.33. The survey indices and catch series used in the production model were the following:

- Nominal catches 1987-2015
- EU 3NO survey (Mean Weight per Tow) from 1997 to 2015.
- EU Flemish Cap survey (Mean Weight per Tow) till 1400 m. from 2004 to 2015.
- EU Flemish Cap survey (Mean Weight per Tow) till 700 m. from 1992 to 2003.
- Canadian Autumn survey 2J+3K (Mean Weight per Tow) till 1000 m. from 1987 to 1994 (Engel).

The survey data was treated in the model formulation as follow: EU 3NO survey index as CPUE type (CC) because this is the longer series cover till 1400 meters and cover the depth distribution of Roughhead grenadier fairly well (Murua and De Cardenas, 2005). The other three series as indices of biomass type (I). UE Flemish Cap indices as annual average index (I1) because it is carried out in July and the Canadian Autumn survey as end of the year index (I2) because normally it is carried out between October and December.

Table 9 presents the ASPIC results. The fit of the observed to the model estimated CPUEs is not good as show the contrast index value (0.43). The main reason is the lack of contrast of the all surveys series used in the analysis. The model is not able to well estimate all parameters due to this lack of contrast on the data. Estimated MSY is at or near maximum bound (1.000E+05) thus the results can trivial. Other fit problem in this run was the negative correlations detected between some indices. A fundamental assumption of ASPIC is that all indices represent the abundance of the stock and one problem in this stock is that there is not available an index covering all the stock distributions. There are only available indices that only cover partiality the stock distribution and may not be representative of the overall trend on the stock. These fit and results problems were similar to the problems found in the 2013 assessment.

Qualitative assessment based on survey and fishery information.

This assessment is qualitative and is based on the survey trend and fishery information. There are not available surveys indices covering the total distribution, in depth and area, of this stock. Canadian Divisions 2J and 3K fall index and the EU survey in Divisions 3NO have been considered till 2010 as the best information in order to monitor trends in resource status (NAFO 2010) because they cover depths down to 1,500 metres and, hence, cover the depth distribution of Roughhead grenadier fairly well (Murua and De Cardenas, 2005). Since 2010, there are available more surveys series cover depths down to 1,500 metres.

Figure 12 presents the relative mean weight per tow for all the series available cover down to 1,500 meters depth. It can be observed a clear increasing trend in the period 1995-2004. In the period 2005-2012 all available indices show a clear downward trend except the Canadian Fall (2J+3K) index. This index presents an increasing trend since 1995 till 2014. In the most recent period (2013-2015) the information of the different indices is contradictory, the Canadian 2J3K and the EU 3L show an increase while EU-FC and EU 3NO continue to decline.

Figure 16 presents the catch / biomass (C/B) indices obtained using all the available survey biomass indices cover till 1400 m depth. The Canadian fall survey and the Spanish 3NO biomass (C/B) indices show a clear decrease trend from 1995 to 2007 and since then are more or less stable at very low level. The other (C/B) indices (EU Flemish Cap, and EU 3L) started in the middle of the twenties and they show a stable low level similar to the Canadian fall and the EU Spanish 3NO surveys in this period.

Figure 17 presents the abundance series (MNPT) for ages 3 of the Canadian fall (2J+3K), the UE Div. 3NO survey and the EU Flemish Cap survey till 1400 m. The transformations of the lengths in ages were made applying the EU Flemish Cap survey ALK to the length indices for all series. Figures 6, 9 and 11 show the length and age distributions of the Canadian fall 2J3K, EU-FC and EU 3NO indices. The tracking of cohorts in time is noisy. This noisy can be due to different factors like ages reading problems for this species, partial coverage of the different surveys, etc. It can be observed at least three good cohorts: 1993, 2001 and 2012 year classes. Normally the EU signals are observed one year later. This could be due to the survey season, at the end of the year in the Canadian autumn survey and in the middle of the year for UE surveys. To confirm the strength of the last good year class (2012) it would need to have more information about it.

The Z values estimated from average catch curves for the most important ages in the catches (6-13) based on Canadian 2J3K (1996-2015), EU-3NO (1997-2015), EU-FC till 1400 meters (2004-2015) and commercial catches information (1992-2015) are presented in Figure 18. The Z estimate from the catch curve based upon commercial catch at age data was 0.19 for ages (R^2=0.79). The value estimate from the Spanish 3NO survey data was 0.21 (R^2=0.88), for the Canadian 2J3K was 0.23 (R^2=0.90) and for EU-FC was 0.13 (R^2=0.79). The values estimated with different data sources are quite similar and estimated a Total mortality around 0.2.

SUMMARY

Three different assessments were presented: Extended Survivors Analysis (XSA), a Stock-Production Model Incorporating Covariates (ASPIC) and a qualitative assessment based on survey and fishery information.

The fit of the data to the XSA and ASPIC has been very poor mainly due to lack of contrast and conflicting information from the available data. Therefore the results are not considered representative of the situation of the stock.

There are not available surveys indices covering the total distribution, in depth and area, of this stock. Biomass indices from the surveys with depth coverage till 1400 meters are considered as the best survey information available to monitor trends in resource status because they cover the depth distribution of roughhead grenadier fairly well.

Surveys biomass indices present a general increasing trend in the period 1995-2004. In the period 2005-2012 all available indices show a clear downward trend except the Canadian Fall (2J+3K) index. In the most recent period (2013-2015) the information of the different indices is contradictory, the Canadian 2J3K and the EU 3L show an increase while EU-FC and EU 3NO continue to decline.

With regard to fishing mortality estimates from different methods, it can be observed that the trends of the different estimations of F were very similar. F presents a decreasing trend since 1998 till 2006 and since then is more or less stable at very low levels.

Despite the difficult to follow cohorts strength, the recruitment indices analysed (Surveys length and age distributions) show at least three good cohorts: 1993, 2001 and 2012 year classes. Normally the EU signals are observed one year later. To confirm the strength of the last good year class (2012) it would need to have more information about it.

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Table 1. STACFIS Roughhead grenadier NAFO Subarea 2 and 3 nominal catches (t) by Division.

	STACFIS RHG Nominal catches (t) by Division									
Year	**2G**	**2H**	**2J**	**3K**	**3L**	**3M**	**3N**	**3O**	**Other**	**TOTAL**
1987					912	7	82			1001
1988		1			907		52			960
1989		2		3	289	28	11			333
1990		1	32		2211	688	312			3244
1991[a]			12	113	2543	497	1093	10		4268
1992			23	274	2582	2961	760	125		6725
1993			10	193	996	1428	1680	61	27	4395
1994	1		2	35	585	2301	1062	28	9	4023
1995	22	6	16	16	1199	1625	1074	20	4	3982
1996					1945	888	1300	2		4135
1997	36	5	63	100	1774	922	1797	43		4740
1998					2766	2190	2230	84	92	7362
1999				61	2037	3127	1705	180	49	7159
2000				139	1382	2109	888	38	211	4767
2001				97	1465	753	754	48		3117
2002				147	1905	869	700	36		3657
2003[b]	1	4	16	91	1342	886	1201	443		3984
2004	4	8	19	58	1310	844	897	42		3182
2005		1	15	93	642	457	235	13		1456
2006			21	54	696	488	111	6	44	1420
2007			10	22	294	191	146	1		664
2008	0	0	1	3	347	355	132	9		847
2009				6	379	136	102	6		629
2010			7	24	649	153	94	14		941
2011			1	61	426	294	224	1		1016
2012			3	14	652	511	119	5		1304
2013			1	1	202	146	48	0		398
2014			0	1	213	355	44			613
2015					116	78	37	0		231

[a] Catch could not be well estimated; based on revised data is estimated to be 8000 to 14000 t. mixed roundnose and rouhhead grenadiers. (Power and Parson 1988).

[b] In 2003, STACFIS could not precisely estimate the catch.

In 2011-2014 STATLANT 21A values

In 2015 DCR values

Table 2. Roughhead grenadier Subarea 2 and 3 catches length distributions and ALK available by country and year.

Data		Length		ALK
Country	Spain	Portugal	Russia	Spain
1992	X	X		
1993	X			
1994	X			
1995	X	X		
1996	X	X		
1997	X	X	X	
1998	X	X	X	
1999	X	X	X	X
2000	X	X	X	X
2001	X	X	X	
2002	X	X	X	X
2003	X	X	X	X
2004	X	X	X	X
2005	X	X	X	X
2006	X	X	X	X
2007	X	X	X	X
2008	X	X	X	X
2009	X	X	X	X
2010	X	X	X	X
2011	X	X	X	X
2012	X	X	X	X
2013	X	X	X	X
2014	X	X	X	X
2015	X	X	X	X

In black only commercial information; in red commercial and Flemish Cap survey information

Table 3. Roughhead grenadier Subarea 2 and 3 total catches length distributions ('000) by year measure as pre anal fin length (AFL), samples and catches.

LENGTH Length (cm)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	30	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
5	4	0	3	0	0	0	0	15	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
6	12	7	5	0	0	0	0	8	0	1	1	4	3	0	0	0	0	0	0	1	1	0	0	1
7	12	12	16	4	0	10	7	12	4	3	5	22	24	1	2	0	1	2	4	3	6	1	9	5
8	11	29	33	8	3	63	21	45	32	16	16	44	39	3	8	4	3	12	21	25	37	5	54	15
9	39	115	67	43	17	121	57	126	112	59	59	102	70	6	19	10	10	42	68	38	80	15	95	39
10	69	51	159	308	212	287	221	157	224	150	162	233	168	12	56	21	22	84	165	99	177	40	225	44
11	101	65	132	231	328	518	448	278	327	210	238	333	256	20	99	32	56	178	283	220	354	66	364	86
12	146	100	150	306	647	529	687	517	474	343	378	444	350	41	157	48	137	243	550	532	740	128	677	127
13	223	255	212	314	771	515	835	651	714	519	492	456	399	93	147	51	138	166	312	336	458	60	223	68
14	531	288	370	412	796	654	1290	591	810	853	727	761	497	133	156	49	169	121	232	181	266	36	92	38
15	742	368	418	529	705	811	2241	698	863	912	950	951	552	167	187	58	201	119	207	172	192	39	128	39
16	755	623	517	515	569	943	2287	719	103 8	719	967	113 4	621	214	233	49	212	97	191	159	229	49	75	26
17	710	850	774	612	615	752	1777	807	118 5	657	782	100 5	632	277	234	47	216	64	126	141	155	53	64	30
18	678	802	813	681	653	642	1093	660	891	589	600	769	541	268	276	46	128	72	107	106	141	44	57	22
19	720	560	690	671	504	572	902	725	680	456	389	557	371	219	197	46	91	50	79	79	90	44	26	19
20	571	421	471	418	503	528	561	709	417	279	253	356	263	172	114	40	72	28	54	64	74	35	34	14
21	551	245	299	282	511	333	402	580	241	155	158	244	191	121	60	43	29	16	49	50	63	34	38	13
22	494	203	211	185	189	228	281	358	171	95	117	154	154	82	51	34	29	18	30	36	40	20	17	11
23	350	219	174	97	155	210	216	380	139	66	75	117	90	59	37	31	17	12	24	35	48	22	17	10
24	395	231	149	91	63	154	213	276	84	53	61	94	93	55	30	27	17	14	21	25	34	19	12	9
25	198	204	150	60	60	128	115	258	99	46	57	71	66	36	31	26	8	17	15	31	37	12	7	9
26	176	188	113	66	62	79	96	167	96	41	50	49	43	22	18	23	11	16	18	29	28	10	10	7
27	121	109	88	73	14	47	49	166	65	32	40	45	41	23	16	20	19	10	15	28	26	12	4	5
28	131	74	64	59	50	45	74	125	44	29	43	36	29	14	21	18	6	10	7	21	20	8	3	3
29	117	75	47	48	60	54	29	87	37	24	42	26	27	12	12	15	2	7	2	13	18	7	3	3

30	64	52	49	17	85	41	30	69	14	19	31	39	22	8	9	10	1	6	3	11	19	7	3	2
31	46	50	28	31	17	35	38	70	21	18	25	21	20	7	6	8	1	4	3	3	11	2	3	1
32	38	55	28	25	0	23	57	60	18	8	21	13	17	9	7	4	5	6	2	3	5	2	1	0
33	22	11	15	15	0	27	12	73	9	9	16	7	7	8	4	3	1	2	2	2	3	1	0	0
34	17	13	15	9	10	18	14	35	10	9	12	8	7	4	7	3	0	2	1	1	2	1	1	0
35	8	9	9	1	0	6	13	21	9	7	10	9	5	5	5	2	1	3	0	0	0	1	0	0
36	8	4	3	0	0	5	11	21	18	3	8	6	2	4	1	1	1	0	0	0	0	1	0	0
37	1	1	4	4	0	0	7	9	15	2	2	2	2	5	1	1	0	1	0	1	1	0	0	0
38	0	0	3	0	0	1	2	9	0	1	1	1	1	2	0	1	0	0	0	0	0	0	0	0
39	1	0	0	0	0	2	0	2	0	2	1	0	0	2	0	0	1	0	0	0	0	0	0	0
40	14	0	2	0	0	2	0	0	12	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0
TOTAL	8080	6291	6281	6114	7598	8385	14085	9584	8875	6386	6789	8114	5609	2104	2208	770	1606	1423	2593	2446	3356	775	2241	643
Samples	219	48	288	234	229	225	34	164	214	299	276	150	188	106	152	97	61	133	104	45	56	40	52	51
Total catch (t)	6725	4395	4023	3982	4135	4740	7270	7160	4767	3117	3657	4179	3290	1456	1420	664	847	629	941	1016	1303	389	595	231

Table 4. Roughhead grenadier Subarea 2 and 3 total catches age distributions ('000), mean weights by age in gr. and mean length at age in cm.

Abundance ('000)

Age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	4	0	1	0	0	0	0	106	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
2	33	38	40	14	5	42	22	129	32	16	6	37	4	0	1	0	0	1	0	1	1	0	1	4
3	62	125	131	143	95	242	145	156	190	107	100	173	121	4	4	1	3	13	0	16	22	9	22	47
4	104	84	178	319	315	468	392	224	302	217	257	464	267	15	17	14	27	80	113	111	235	32	243	117
5	198	151	206	370	709	653	791	641	528	422	483	372	564	41	122	65	103	109	497	393	477	91	472	155
6	509	367	395	565	116 2	926	162 0	950	111 8	916	104 6	563	595	105	212	88	267	429	741	672	948	144	697	72
7	793	496	528	620	924	992	221 3	962	983	105 0	974	119 0	736	222	323	106	371	238	348	447	514	85	193	63
8	1122	948	901	879	999	127 1	301 5	123 8	134 2	117 0	126 6	170 9	100 2	329	325	83	266	240	405	339	408	88	164	41
9	1080	1088	106 2	912	922	107 1	222 6	104 0	169 3	913	874	135 5	712	410	358	56	207	90	232	229	233	82	96	38
10	841	761	799	686	699	717	121 6	808	104 5	565	454	773	499	387	251	82	149	46	102	194	182	76	63	38
11	798	536	587	519	609	583	801	919	473	357	443	396	273	191	191	83	83	50	50	82	99	65	44	20
12	752	456	458	377	457	477	586	542	414	243	318	300	289	143	76	56	44	30	46	70	66	37	28	15
13	582	373	322	231	279	327	376	623	234	138	168	141	171	104	56	40	36	30	30	55	61	20	14	16
14	478	305	245	170	145	233	264	471	186	89	91	63	88	67	49	33	17	22	21	48	44	18	2	7
15	259	197	148	98	84	119	132	228	121	54	59	54	46	22	23	18	12	10	5	32	33	8	4	5
16	162	121	90	76	60	81	83	106	63	37	60	71	41	10	9	15	8	8	3	18	13	5	3	2
17	100	74	55	45	48	62	47	69	28	25	69	33	21	14	17	9	6	7	4	6	13	6	3	1
18	76	65	46	35	42	44	48	97	22	22	51	12	18	12	8	9	4	3	2	5	4	3	2	1
19	54	52	37	24	30	33	42	79	31	17	28	16	8	11	3	5	1	6	1	2	1	2	1	0
20	30	28	23	15	9	21	29	81	19	12	16	7	5	7	2	5	2	3	0	3	3	1	0	0
21	18	17	13	9	2	14	19	56	18	7	12	0	3	3	2	2	0	3	0	0	1	0	0	0
22	8	4	7	3	1	5	8	28	13	5	5	2	0	3	0	0	0	0	0	1	0	1	0	0
23	9	4	5	2	2	4	7	23	10	4	5	0	0	2	0	1	0	2	1	0	0	0	0	0
24	8	1	4	1	0	2	3	8	10	3	3	1	1	0	0	0	0	1	0	0	0	1	0	0
Total	8080	6291	628 1	611 2	759 8	838 5	###	958 4	887 5	638 8	679 0	773 6	546 7	210 4	204 7	770	160 6	142 3	260 1	272 3	335 6	775	205 3	643

Mean Weight (gr)																										
Age	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2007**	**2008**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
1	11		16				30	10	14	13	22	34	4	4		68										
2	40	51	49	80	165	107	107	127	116	99	61	91	41	62	16	93	68			90		31	35	28	38	38
3	86	77	85	113	156	147	143	180	158	137	154	148	102	80	109	105	102	52	56	118	38	53	57	72	52	77
4	119	111	115	143	184	211	177	244	194	176	218	213	192	114	161	161	167	90	97	164	98	90	105	95	96	125
5	186	184	173	230	216	262	229	317	243	227	268	278	269	195	212	256	245	147	162	212	165	138	137	136	144	172
6	258	236	236	325	260	300	281	365	276	271	306	299	317	262	265	383	342	213	227	262	220	179	182	178	179	239
7	337	320	313	434	348	355	342	434	327	324	353	333	375	343	343	410	397	305	302	321	297	239	261	247	253	285
8	440	414	412	524	451	421	403	487	393	397	414	423	473	437	434	516	503	423	426	444	396	364	378	371	359	399
9	594	500	509	612	560	516	490	591	498	499	498	483	568	538	561	619	602	494	486	556	549	479	516	502	505	520
10	748	585	590	677	653	618	600	677	568	587	607	616	726	669	609	848	807	527	566	648	744	638	656	664	720	664
11	922	736	716	776	767	743	749	785	725	709	692	854	836	810	788	1095	1116	665	686	817	887	849	898	872	853	889
12	1063	886	836	885	851	855	876	949	828	824	840	979	1072	988	1023	1199	1203	832	853	1067	1135	1103	1121	1081	1058	1077
13	1226	1101	1039	1106	984	1033	1052	1151	1068	1033	989	1155	1361	1131	1282	1655	1589	1308	1325	1287	1416	1341	1332	1381	1365	1357
14	1446	1324	1280	1443	1245	1252	1299	1305	1353	1343	1412	1521	1546	1198	1709	1876	1829	1209	1268	1544	1689	1561	1637	1645	1858	1565
15	1683	1546	1530	1705	1696	1534	1544	1657	1561	1652	1565	1903	2234	1783	2160	1957	2119	816	1590	1617	1808	1752	1958	1915	1688	1730
16	1928	1777	1729	1966	1837	1799	1823	1832	1787	1851	1852	1998	2330	2282	2457	2374	2375	1703	1909	1914	2266	1974	2217	2143	1778	1912
17	2212	1989	2005	2220	2083	2257	2100	2023	2010	2132	2078	2407	2393	2578	2808	3715	2903	1853	2026	2301	2509	2316	2425	2233	2419	2352
18	2478	2326	2333	2459	2197	2421	2466	2358	2441	2429	2440	3056	2496	2948	3377	2527	2786	1586	1788	2459	2655	2384	2673	2536	2440	2367
19	2669	2508	2553	2643	2283	2534	2707	2474	2716	2662	2822	2954	2675	3426	3502	3065	2741	3220	3241	2562	2923	2575	2803	2745	3047	2973
20	3052	2777	2889	2887	2643	2870	2942	2887	3207	3000	3140	2899	2719	3199	4089	3251	3269	1995	2037	2843	2997	2779	2851	2826	3056	3565
21	3363	2898	3076	3029	3105	3198	3063	3036	3739	3263	2939	4177	3773	3411	5186	4213	3031	3639	3837	3465	3192	2971	3806	3622		
22	3993	3422	3637	3487	3192	3471	3663	3584	3851	3754	3807	3682	4384	4287		3830	4255	4255	3757	3477	3841	2868		4506	3834	
23	4092	3299	3525	3556	2514	3485	3592	3699	4289	3787	3240	4206	4534	3476		3369	3830			3126	3549	4169		3829		4298
24	4998	4172	4453	4067		4541	4108	4442	4670	4493	4206	4220	4820							2873	4384	4062	4648	3408	2699	

Mean Length (cm)																										
Age	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2007**	**2008**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
1	4.7		5.5				5.1	3.6	4.7	4.1	4.0	4.8	2.2	3.5		6.5										
2	7.4	8.1	8.0	9.2	9.9	8.8	8.6	8.9	8.9	8.9	7.3	7.7	5.3	7.0	5.4	7.4	6.5			7.4		7.0	6.5	6.7	7.3	7.3
3	9.8	9.5	9.8	10.2	10.4	9.8	10.1	9.9	9.9	9.9	9.7	9.7	8.9	9.0	8.4	8.1	8.0	8.3	8.4	8.8	7.5	8.4	8.2	9.2	8.2	9.4
4	11.0	10.7	10.9	10.9	11.2	11.1	11.2	11.3	11.0	11.1	11.1	11.2	11.1	10.4	10.1	9.5	9.7	10.0	10.2	10.1	9.4	10.1	10.5	10.2	10.0	11.0
5	12.7	12.8	12.5	12.4	12.6	12.4	12.6	12.7	12.5	12.7	12.5	12.5	12.7	12.4	11.6	11.8	11.5	11.9	12.3	11.3	11.5	11.7	11.5	11.5	11.6	12.4
6	14.2	14.0	14.0	13.8	13.7	13.7	14.0	13.7	13.7	13.9	14.1	13.6	13.9	13.7	13.1	14.2	13.5	13.4	13.6	12.5	12.8	12.8	12.8	12.7	12.6	13.9
7	15.4	15.5	15.4	15.3	15.0	15.3	15.4	15.5	15.1	15.2	15.4	15.0	15.3	15.1	15.0	15.1	14.9	15.2	15.2	14.0	14.6	14.0	14.4	14.1	14.1	14.8
8	16.6	17.0	16.9	16.8	16.5	16.6	16.4	16.8	16.3	16.4	16.5	16.7	17.1	16.6	16.8	17.1	16.9	17.1	17.1	16.4	16.3	16.2	16.3	16.3	16.0	16.6
9	18.1	18.1	18.2	18.2	18.1	17.9	17.6	18.5	17.8	17.8	17.7	17.7	18.2	17.9	18.5	18.5	18.3	18.0	17.9	18.1	18.4	17.8	18.2	18.1	18.1	18.2
10	19.5	19.1	19.2	19.2	19.3	19.2	18.9	19.6	18.7	18.9	18.9	19.3	19.8	19.5	19.1	20.3	20.0	18.3	18.8	19.2	20.5	19.7	19.8	19.9	20.4	19.8
11	20.9	20.6	20.5	20.4	20.7	20.6	20.3	20.8	20.3	20.2	19.8	21.5	20.5	20.9	20.8	22.2	22.3	19.9	20.2	20.9	21.9	21.6	22.1	21.9	21.6	22.0
12	22.0	22.0	21.6	21.2	21.4	21.6	21.5	22.2	21.2	21.2	21.0	22.5	22.1	22.5	22.7	23.0	23.0	21.5	21.7	23.2	23.9	23.7	23.9	23.6	23.3	23.5
13	23.3	23.7	23.2	22.7	22.5	23.0	22.9	23.8	23.1	22.8	22.1	23.7	24.0	23.5	24.5	26.1	25.5	25.2	25.3	24.9	25.9	25.4	25.5	25.7	25.5	25.5
14	24.8	25.3	25.0	24.9	24.3	24.6	24.6	24.8	25.0	24.9	25.1	26.1	25.1	23.9	27.2	27.4	27.1	24.2	24.6	26.7	27.6	26.7	27.5	27.3	28.4	26.8
15	26.4	26.7	26.6	26.7	27.2	26.4	26.3	27.1	26.5	26.9	26.0	28.5	29.2	27.7	29.5	27.4	28.3	20.6	26.9	27.0	28.2	27.9	29.2	28.7	27.5	27.7
16	27.7	28.0	27.7	28.1	28.0	27.8	27.7	28.1	27.5	27.9	27.8	28.9	29.8	30.2	30.9	29.7	29.7	27.3	28.3	28.8	30.6	29.1	30.6	29.9	28.0	28.7
17	29.2	29.2	29.2	29.4	29.5	30.3	29.4	29.1	28.8	29.5	29.1	30.9	29.7	31.5	32.3	34.9	32.2	28.4	29.3	30.7	31.6	30.7	31.3	30.3	31.3	30.9
18	30.6	30.8	30.9	30.8	30.2	31.2	31.3	30.8	30.8	31.0	30.9	33.8	30.7	33.1	35.0	30.3	31.2	26.0	27.1	31.5	32.3	31.1	32.8	31.7	31.3	31.0
19	31.5	31.7	31.8	31.5	30.6	31.7	32.3	31.4	32.0	32.0	32.7	33.4	31.3	35.0	35.0	32.3	31.2	34.5	34.6	31.8	33.4	31.8	33.6	32.5	33.9	33.6
20	33.0	32.8	33.2	32.8	32.1	33.2	33.3	33.1	34.1	33.5	34.1	33.1	31.6	34.1	37.2	33.0	33.2	28.8	29.2	33.1	33.8	32.6	33.9	32.9	33.9	35.8
21	34.1	33.3	34.0	33.4	34.1	34.3	33.8	33.8	36.1	34.5	33.2	37.8	36.5	34.9	40.2	36.6	32.5	36.1	36.8	35.4	34.5	33.6	37.7	35.9		
22	36.6	35.3	36.0	35.3	34.5	35.4	36.0	35.8	36.5	36.3	36.5	36.2	38.5	38.1		35.5	36.6	38.0	36.5	35.5	36.7	33.0		38.6	36.7	
23	37.0	34.7	35.5	35.2	31.6	35.3	35.8	36.2	38.0	36.4	34.3	37.9	38.9	35.2		34.0	35.5			34.1	35.8	37.3		36.5		38.2
24	40.2	37.8	38.7	37.5		38.9	37.5	38.7	39.3	38.8	37.8	38.0	39.8				33.8			33.2	38.5	37.5	40.5	35.0	32.5	

Table 5. Available surveys biomass indices for the roughhead grenadier Subareas 2 and 3 stock, with their depth and area coverage.

Survey	Time Series	NAFO Division	Depth Range
Canadian Fall Survey	1978 – 1994	2GHJ 3KLMNO	<730 m
	1995 – 2015	2GHJ 3KLMNO	<1500 m
EU-Spanish Surveys in Div. 3NO	1997 - 2015	3NO	<1500 m
EU-Spanish Surveys in Div. 3L (Flemish pass)	2003-2004; 2006-2015	3L	100-1500 m.
EU Flemish Cap Surveys	1988 – 2003	3M	<730 m
	2004– 2015	3M	<1500 m
Canadian Spring Survey	1991 - 2015	3LNO	<730 m
Canadian deepwater	1991, 1994, 1995	3LMN	<1500 m
Russian	2001 - 2002	3M	120 - 1280 m
EU Deepwater	1996	3LMN	700 - 3100m

Table 6. Available roughhead grenadier surveys biomass indices series. Mean Weight Per Tow for all except the Canadian Spring survey and Canadian deepwater survey are measure as total biomass.

Year	EU-Spa 3NO	EU-Spa 3L	EU FC (>700)	EU FC (>1400)	Can Fall (2J+3K)	Can Spring	Can Deepwater
1978					7.00		
1979					5.88		
1980					7.29		
1981					4.66		
1982					5.67		
1983					5.22		
1984					4.82		
1985					2.49		
1986					2.49		
1987					2.12		
1988					1.91		
1989					1.20		
1990			1.06		2.36		
1991			1.66		1.60	270	
1992			1.96		0.59	1141	16215
1993			3.76		0.48	561	
1994			2.46		0.31	675	
1995	0.10		1.94		0.65	358	26588
1996	0.94		1.69		1.29	2883	46668
1997	3.81		1.49		1.48	3103	
1998	7.05		2.10		1.71	5078	
1999	4.53		1.55		1.50	4043	
2000	7.08		1.30		1.66	5095	
2001	5.73		2.59		2.45	4948	
2002	5.46		1.51		1.91	3116	
2003	7.40	21.16	2.92		1.73	4297	
2004	12.09	29.38	4.47	14.04	2.57	4361	
2005	11.10	*	2.97	10.26	2.42	15608	
2006	11.11	30.52	4.89	9.26	2.60	5415	
2007	6.93	29.77	1.70	5.94	3.02	13475	
2008	7.93	34.18	3.68	9.91	2.06	4977	
2009	9.15	27.17	0.97	5.96	3.41	4300	
2010	6.97	23.70	1.74	7.43	3.62	5722	
2011	6.82	18.57	0.86	7.19	4.34	4577	
2012	8.59	16.50	0.76	4.47	3.36	6713	
2013	5.81	24.77	1.00	3.52	4.20	3790	
2014	4.08	20.86	0.50	3.36	5.03	3510	
2015	6.79	31.63	0.59	3.02	3.62	2402	

* Not available
In yellow, series with Engel 145 gear and in the case of the Can 2J+3K till 1000 meters depth coverage.
Years with coverage problems in red.

Table 7. XSA result for Recruitment (Age 3), Total biomass, catches and Fbar (6-13).

Year	Recruits ('000)	TotalBio (ton)	Catches (ton)	Fbar
1992	17761	36252	6725	0.239
1993	26932	32702	4395	0.187
1994	28525	34519	4023	0.181
1995	24715	45353	3982	0.130
1996	24755	46388	4135	0.137
1997	28406	50489	4740	0.131
1998	31716	54801	7362	0.219
1999	26399	68448	7159	0.170
2000	23689	61071	4767	0.136
2001	19402	62050	3117	0.081
2002	20551	70382	3657	0.076
2003	20150	65937	3984	0.077
2004	23415	75950	3182	0.054
2005	21457	85834	1456	0.026
2006	18761	112657	1420	0.023
2007	15361	115104	664	0.008
2008	14468	80904	847	0.016
2009	12112	111469	629	0.013
2010	12010	115418	941	0.023
2011	14349	92156	1016	0.029
2012	16568	100517	1304	0.040
2013	17139	115433	398	0.010
2014	20017	90738	613	0.021
2015	22868	87050	231	0.006

Table 8. ASPIC input file specifications.

```
FIT                          ## Run type (FIT, BOT, or IRF)
"NAFO Subareas 2+3 RHG 2015"
LOGISTIC  YLD    SSE
112                           ## Verbosity
500  50                       ## Number of bootstrap trials, <= 1000
0  20000                      ## 0=no MC search, 1=search, 2=repeated srch; N trials
1.0000E-08                   ## Convergence crit. for simplex
3.0000E-08  6                ## Convergence crit. for restarts, N restarts
1.0000E-04  12               ## Conv. crit. for F; N steps/yr for gen. model
8.0000                       ## Maximum F when cond. on yield
1.0                          ## Stat weight for B1>K as residual (usually 0 or 1)
4                             ## Number of fisheries (data series)
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00        ## Statistical weights for data series
0.5000                       ## B1/K (starting guess, usually 0 to 1)
5.0000E+03                   ## MSY (starting guess)
1.0000E+05                   ## K (carrying capacity) (starting guess)
2.0000E-04  9.0000E-05  6.0000E-05  6.0000E-05        ## q (starting guesses -- 1 per data series)
1  1  1  1  1  1  1           ## Estimate flags (0 or 1) (B1/K,MSY,K,q1...qn)
5.0000E+02  1.0000E+05                                ## Min and max constraints -- MSY
1.0000E+04  5.0000E+06                                ## Min and max constraints -- K
1900285                      ## Random number seed
29                           ## Number of years of data in each series
```

Table 9. ASPIC results.

```
PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                                                  error code  11
-------------------------------------------------------------------------------------------------------------------------------------
ERROR: Estimate of MSY is at or near maximum bound, 1.000E+05
       Solution may be trivial--examine carefully.

WARNING: Negative correlations detected between some indices.  A fundamental assumption of ASPIC is that all indices
         represent the abundance of the stock. That assumption should be checked.
Number of restarts required for convergence:     12


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
-------------------------------------------------------------------------------------------------------------------------------------
                                    |
 1  Spanish 3NO (1400 m)            |   1.000
                                    |     19
                                    |
 2  Spanish Flemish Cap (1400 m)    |   0.796   1.000
                                    |     12      12
                                    |
 3  3M Flemish Cap (700 m)          |   0.653   0.865   1.000
                                    |     19      12      24
                                    |
 4  Canadian 2J3K, 1000             |   0.000   0.000  -0.149   1.000
                                    |      0       0       3       8
                                   ------------------------------------------
                                          1       2       3       4


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
-------------------------------------------------------------------------------------------------------------------------------------
                                                        Weighted                 Weighted      Current     Inv. var.     R-squared
Loss component number and title                            SSE       N              MSE       weight       weight      in CPUE

Loss(-1)  SSE in yield                                0.000E+00
Loss(0)   Penalty for B1 > K                          0.000E+00       1              N/A    1.000E+00          N/A
Loss(1)   Spanish 3NO (1400 m)                       1.795E+00      19    1.056E-01    1.000E+00    2.054E+00       -0.001
Loss(2)   Spanish Flemish Cap (1400 m)               2.769E+00      12    2.769E-01    1.000E+00    7.831E-01       -0.064
Loss(3)   3M Flemish Cap (700 m)                     9.074E+00      24    4.124E-01    1.000E+00    5.258E-01       -0.097
Loss(4)   Canadian 2J3K, 1000                        5.334E+00       8    8.890E-01    1.000E+00    2.440E-01       -0.402
.....................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:          1.89716595E+01                3.388E-01    5.820E-01
Estimated contrast index (ideal = 1.0):             0.4332                 C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):             0.9352                 N* = 1 - |min(B-Bmsy)|/K
‡NAFO Subareas 2+3 RHG 2015                                                                                        Page 2


MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-------------------------------------------------------------------------------------------------------------------------------------
Parameter                                              Estimate     User/pgm guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1987)       5.648E-01          5.000E-01    4.206E-01           1            1
MSY       Maximum sustainable yield                 1.000E+05          5.000E+03    2.360E+03           1            1
K         Maximum population size                   1.318E+06          1.000E+05    1.416E+04           1            1
phi       Shape of production curve (Bmsy/K)        0.5000             0.5000            ----           0            1

--------- Catchability Coefficients by Data Series ---------------
q(1)      Spanish 3NO (1400 m)                      5.347E-06          2.000E-04    1.900E-02           1            1
q(2)      Spanish Flemish Cap (1400 m)              4.833E-06          9.000E-05    8.550E-03           1            1
q(3)      3M Flemish Cap (700 m)                    1.359E-06          6.000E-05    5.700E-03           1            1
q(4)      Canadian 2J3K, 1000                       1.003E-06          6.000E-05    5.700E-03           1            1
```

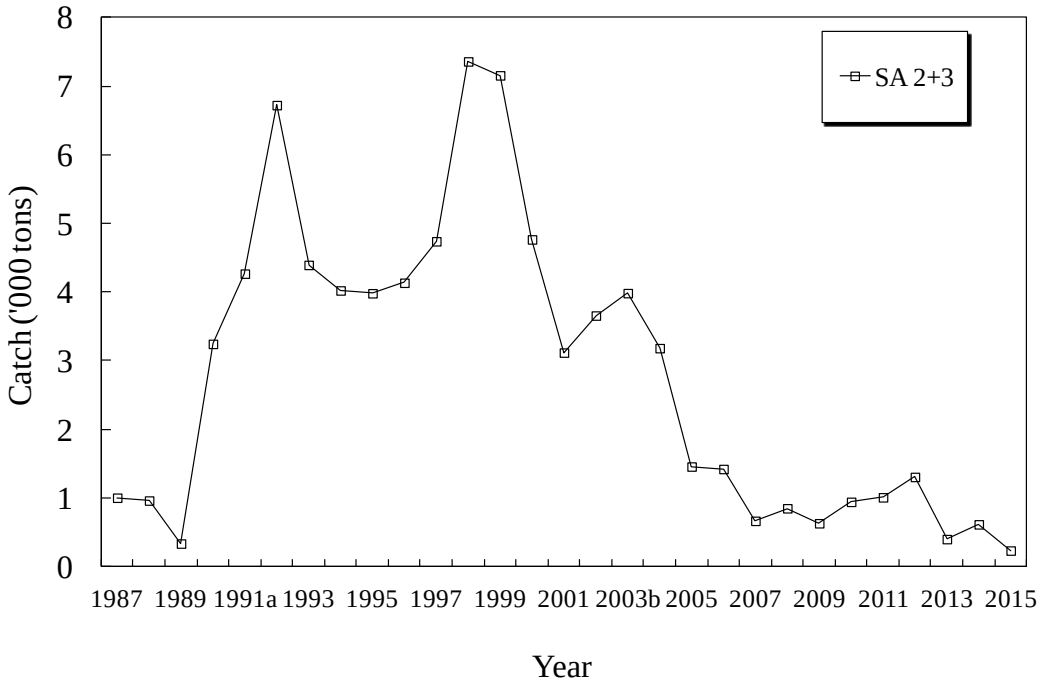

Fig. 1. STACFIS roughhead grenadier NAFO Subarea 2 and 3 nominal catches (t).

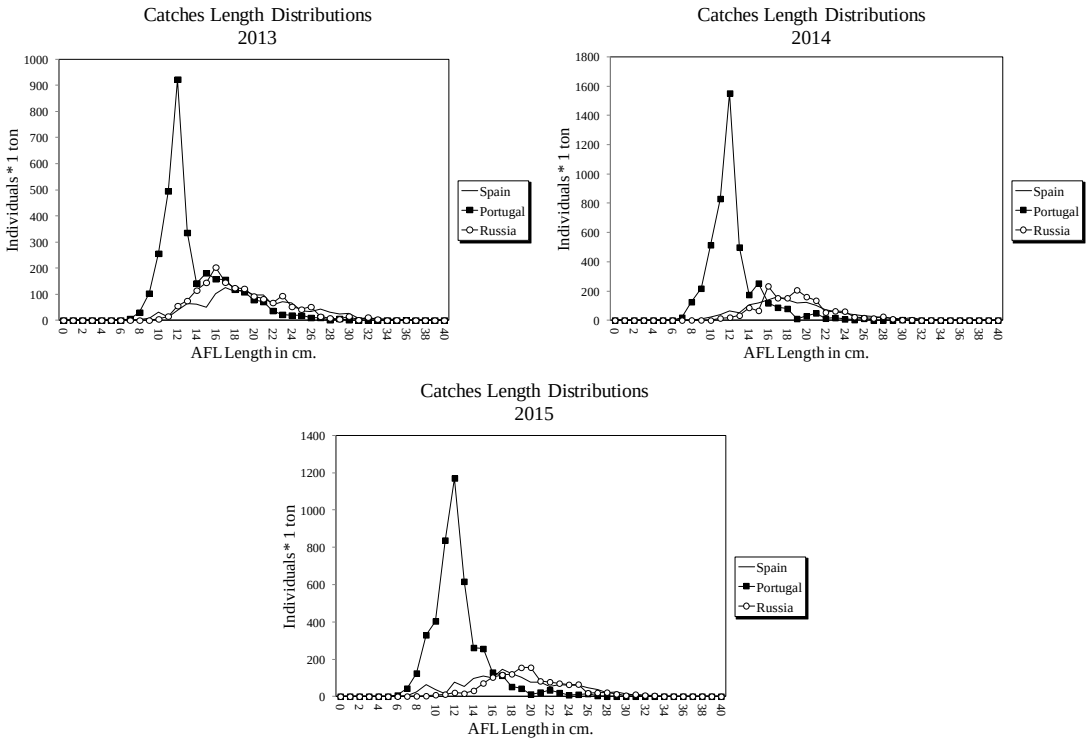

Fig. 2. Subarea 2+3 roughhead grenadier Spanish, Portuguese and Russian catches length distributions (individuals per ton) for 2013-2015.

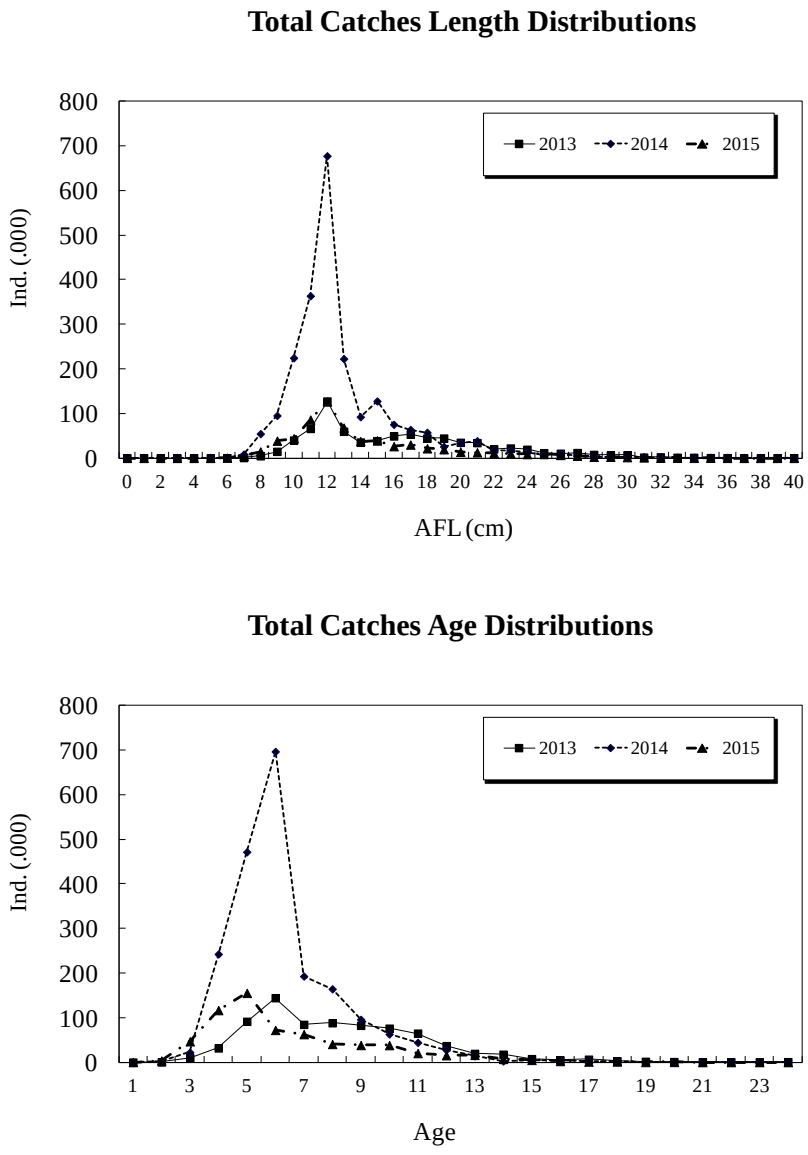

Fig. 3. Subarea 2+3 roughhead grenadier total catches length and Age distributions for 2013-2015.

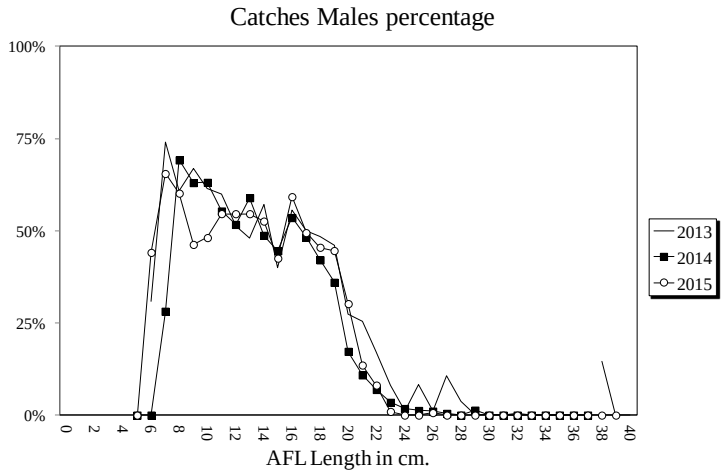

Fig. 4. Subarea 2+3 roughhead grenadier sex ratio by length for 2013-2015. Based on the Spanish, Portuguese and Russian commercial length samples.

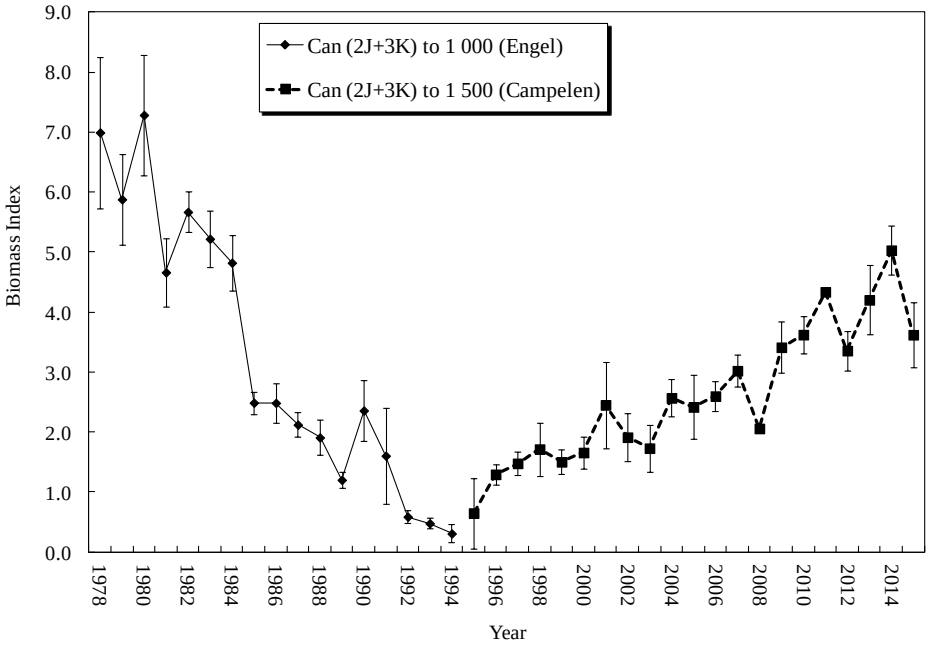

Fig. 5. Roughhead grenadier in Subareas 2+3: biomass index (+/- SE) from the Canadian autumn (Div. 2J3K) survey

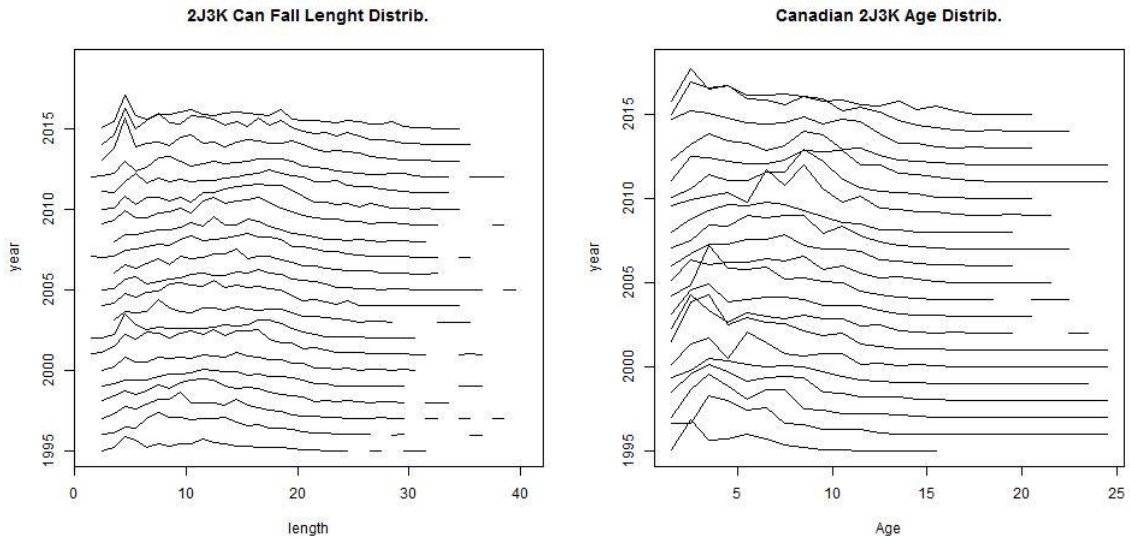

Fig. 6. Roughhead Grenadier length and age frequencies distribution from Canadian Autumn surveys Div. 2J3K.

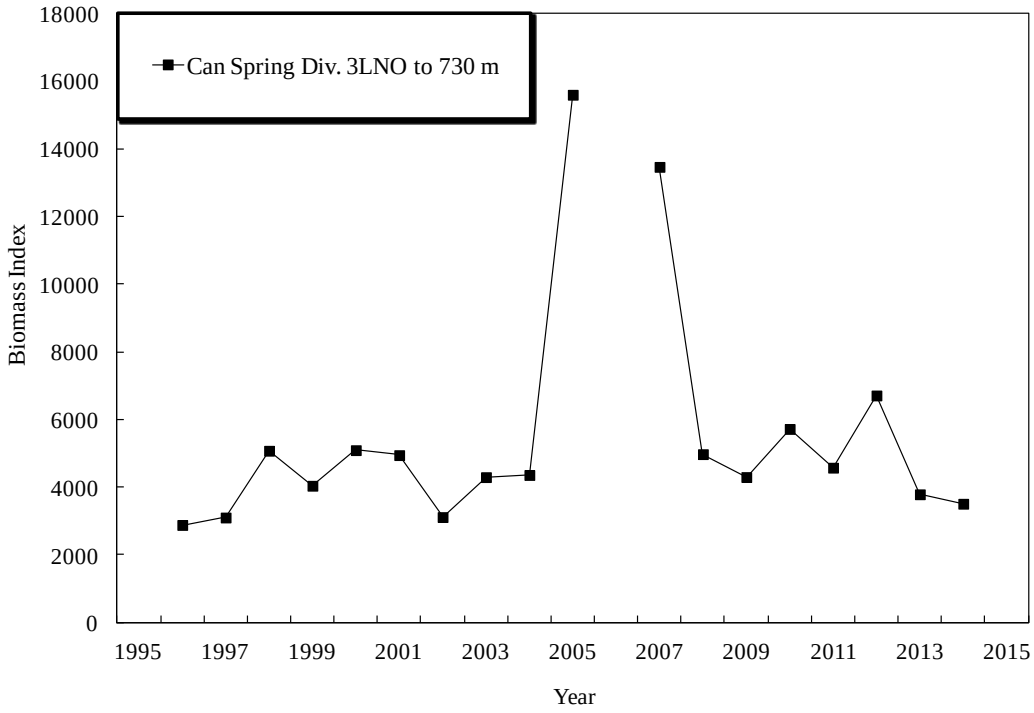

Fig 7. Roughhead grenadier in Subareas 2+3: biomass index from the Canadian spring surveys.

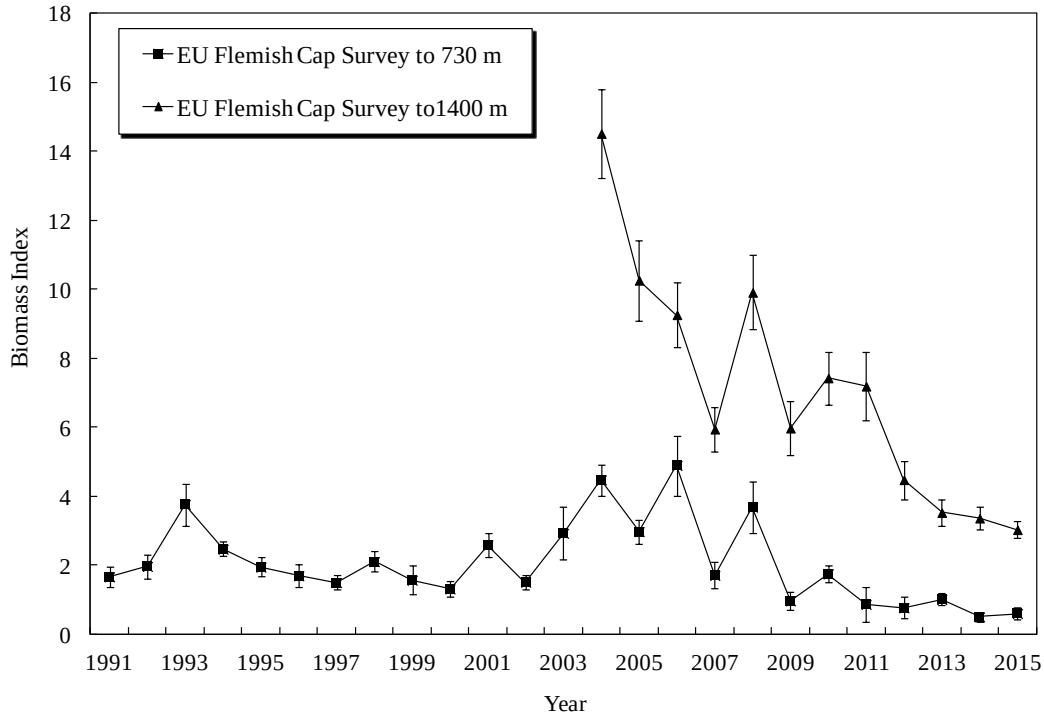

Fig. 8. Roughhead grenadier in Subareas 2+3: biomass index (+/- SE) from the EU Flemish Cap survey.

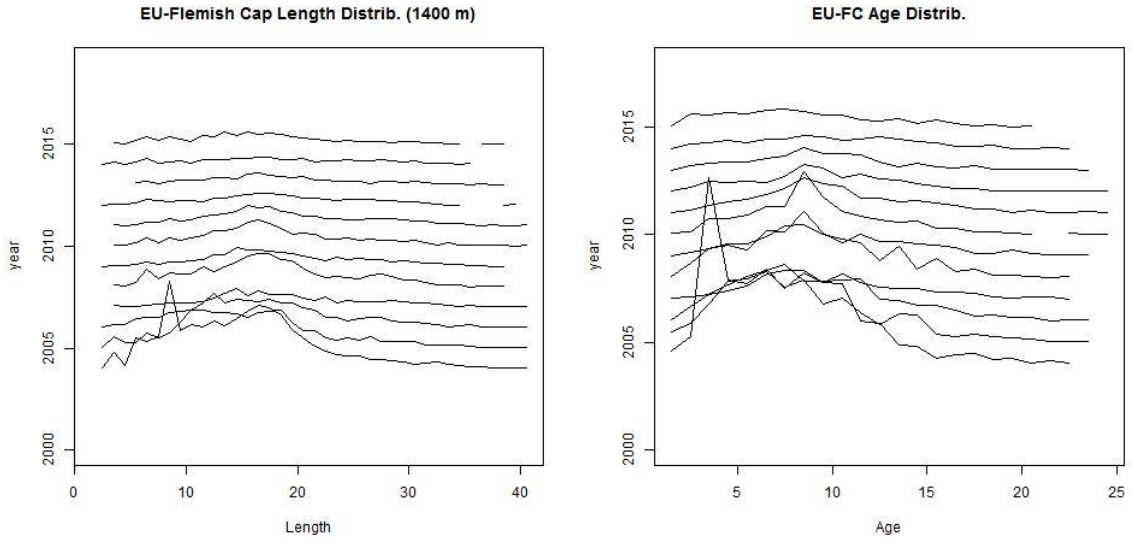

Fig. 9. Roughhead Grenadier length and age frequency distribution from EU Flemish Cap surveys (Div. 3M).

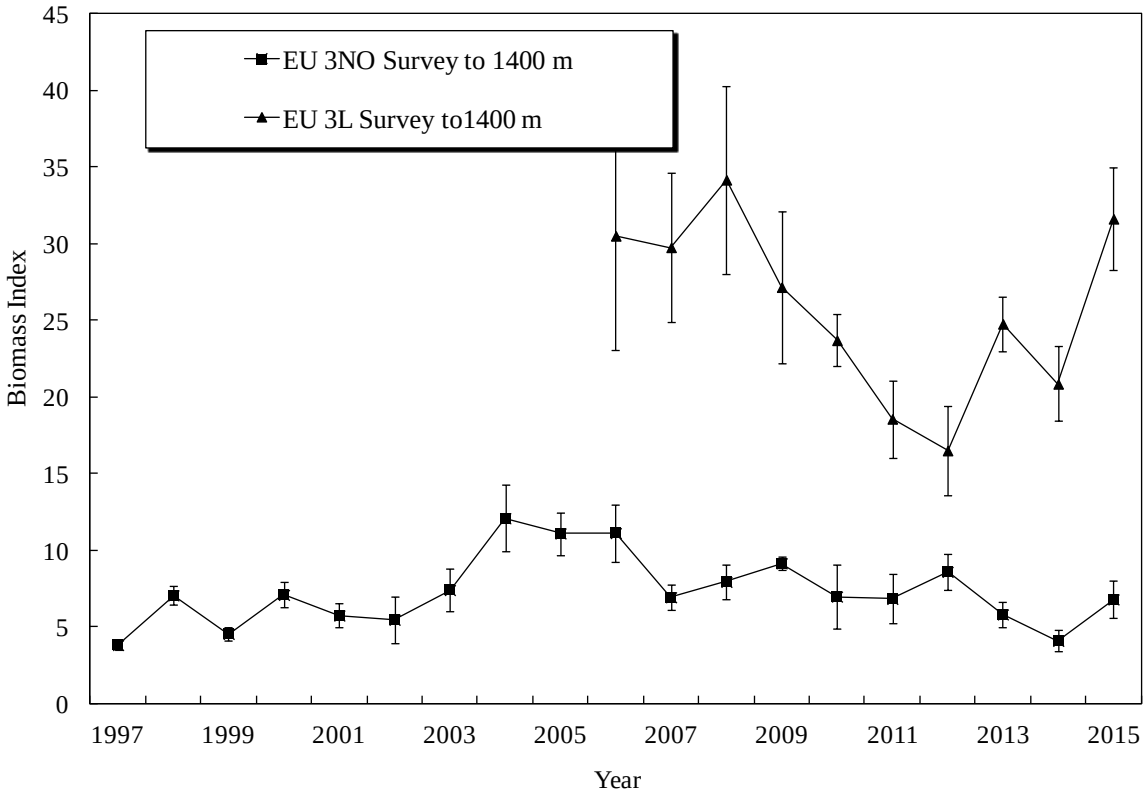

Fig. 10. Roughhead grenadier in Subareas 2+3: biomass index (+/- SE) from the EU Spanish Div. 3NO and 3L surveys.

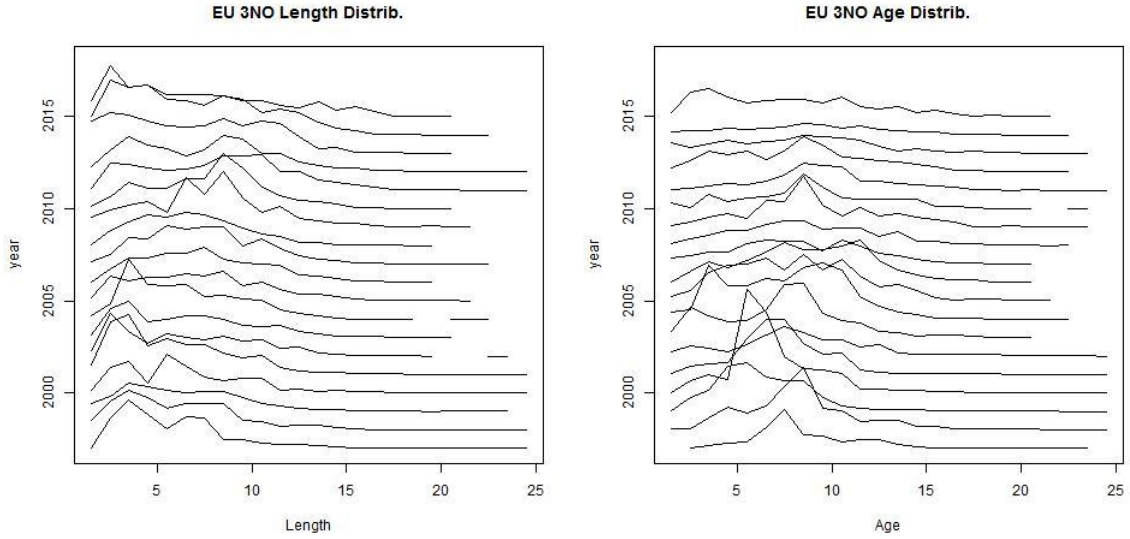

Fig. 11. Roughhead Grenadier length and age frequency distribution from EU 3NO survey.

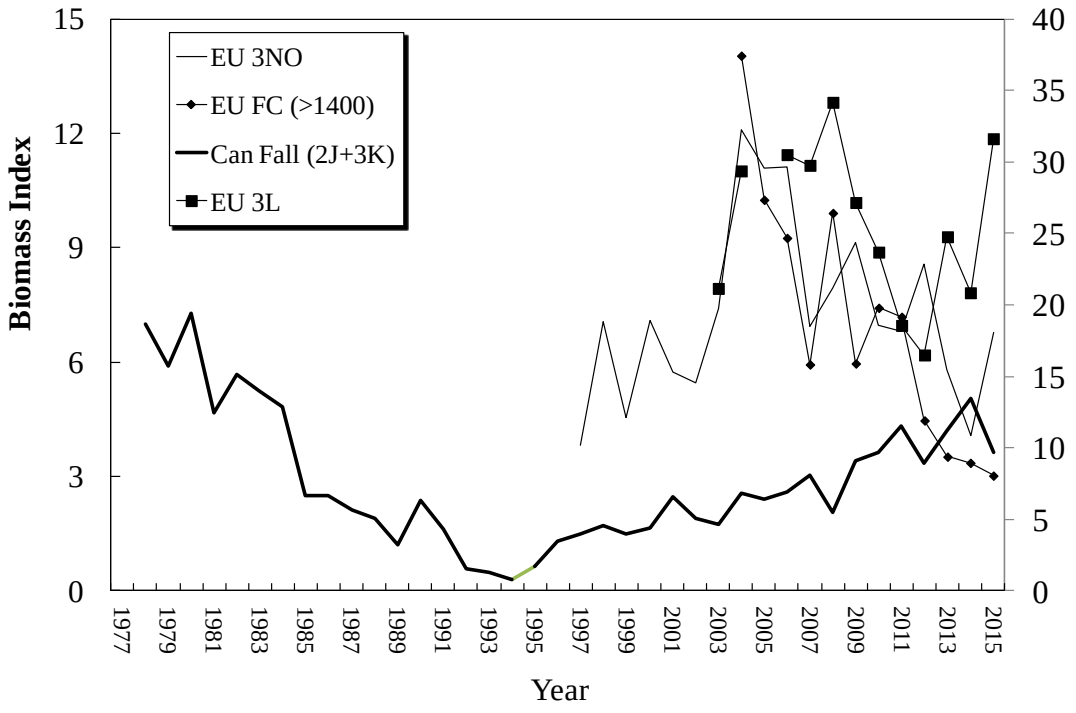

Fig. 12. Roughhead grenadier in Subareas 2+3: MWPT biomass indices from Canadian fall 2J+3K (1978-2015), EU 3NO (1997-2015), EU 3L (2006-2015), and EU Flemish Cap till 1400 m.(2004-2015) surveys.

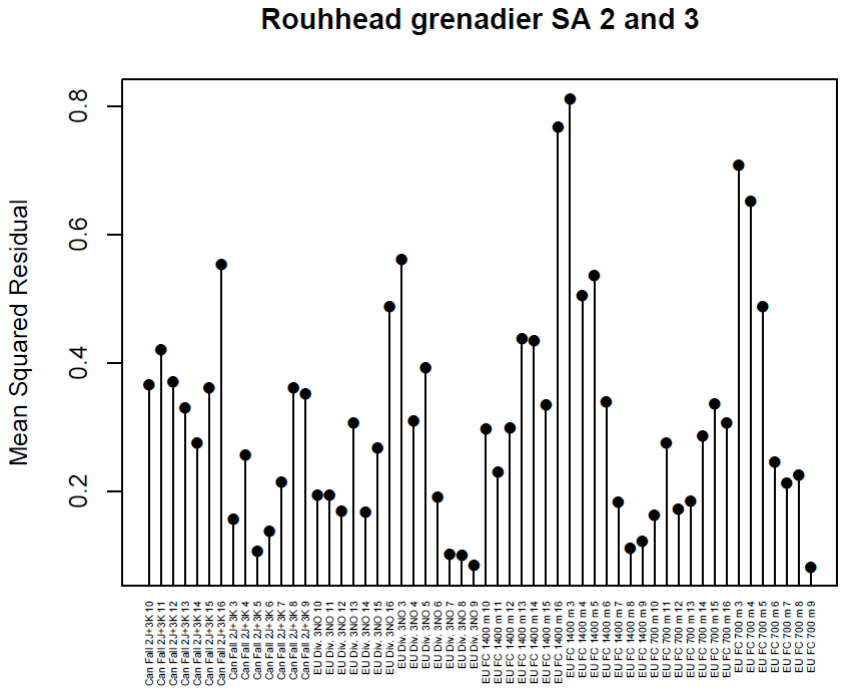

Fig. 13. XSA Standard Error (SE) of the log catchability for the Canadian fall 2J+3K, EU Spanish 3NO and EU Flemish Cap till 1400 and 700 meters surveys by and age.

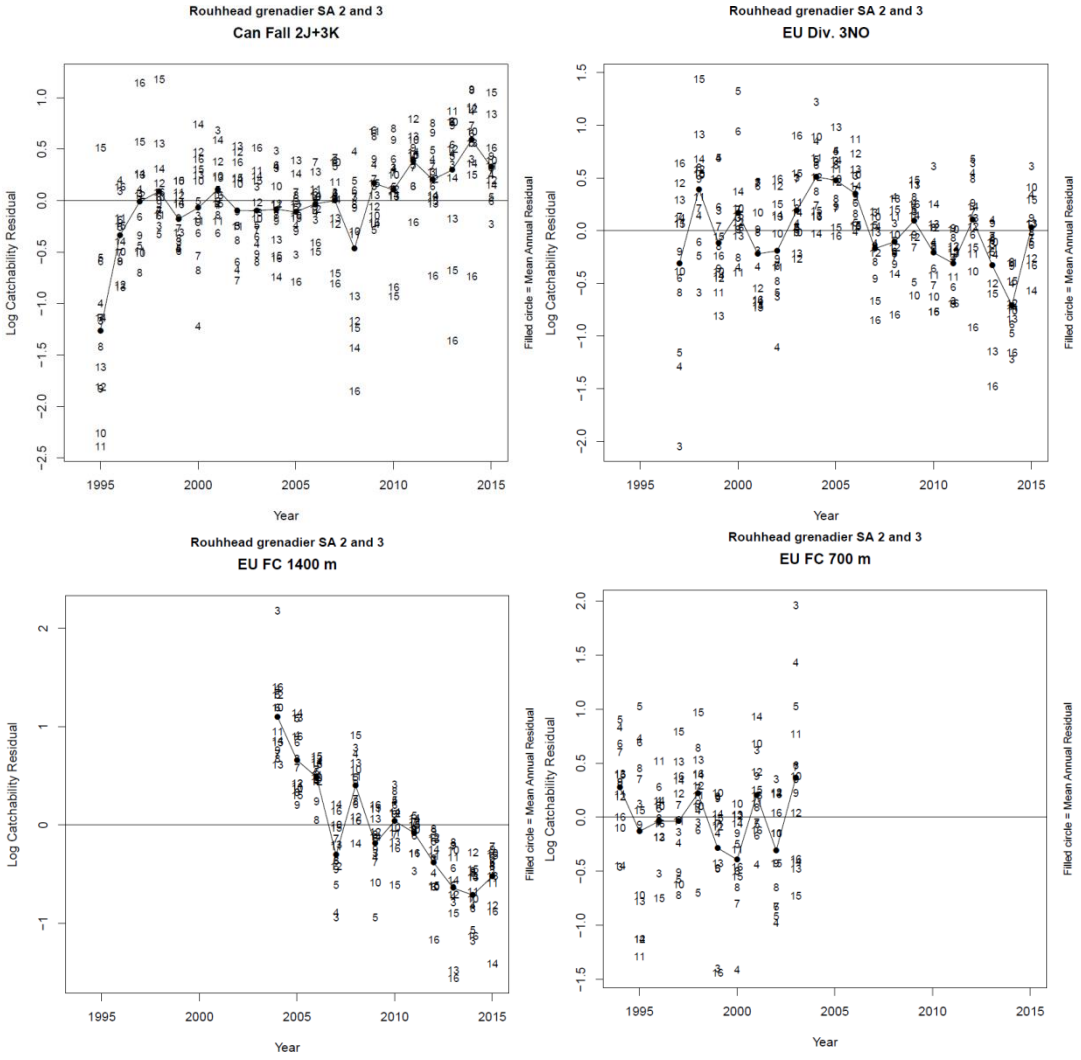

Fig. 14. XSA Log catchability residuals for EU for the Canadian fall 2J+3K, EU Spanish 3NO and EU Flemish Cap till 1400 and 700 meters by year and age.

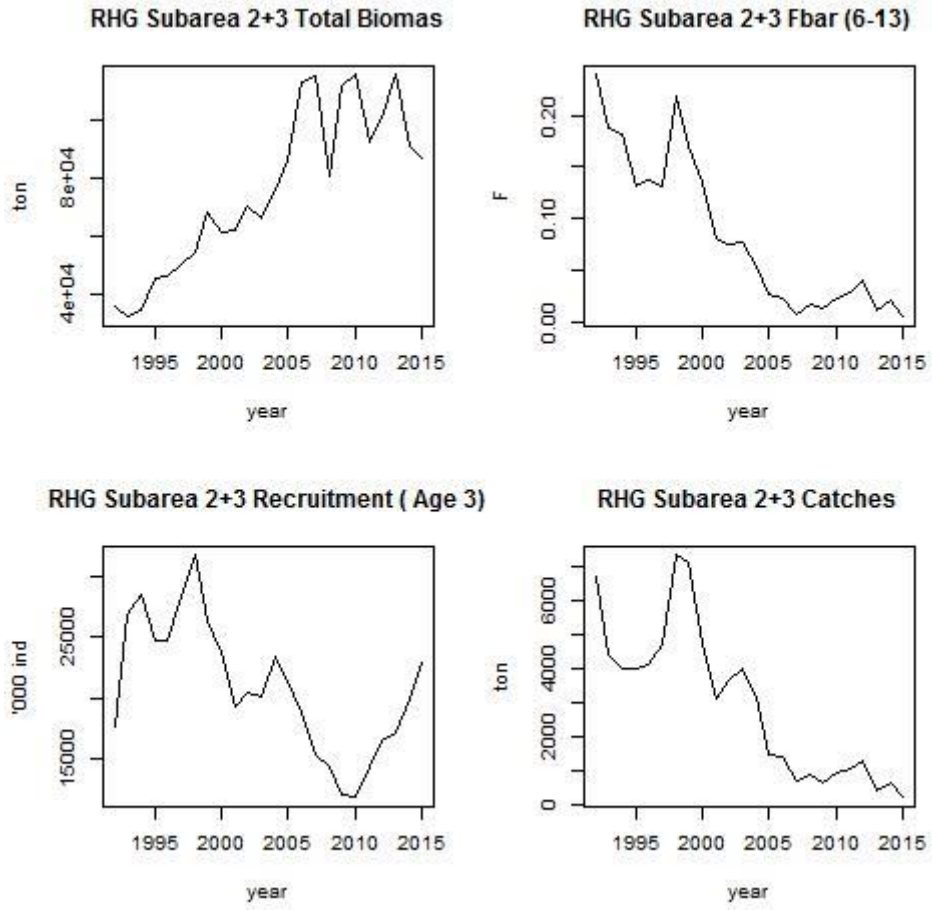

Fig. 15. XSA result for Total biomass, Fbar (6-13), recruitment (Age 3) and catches.

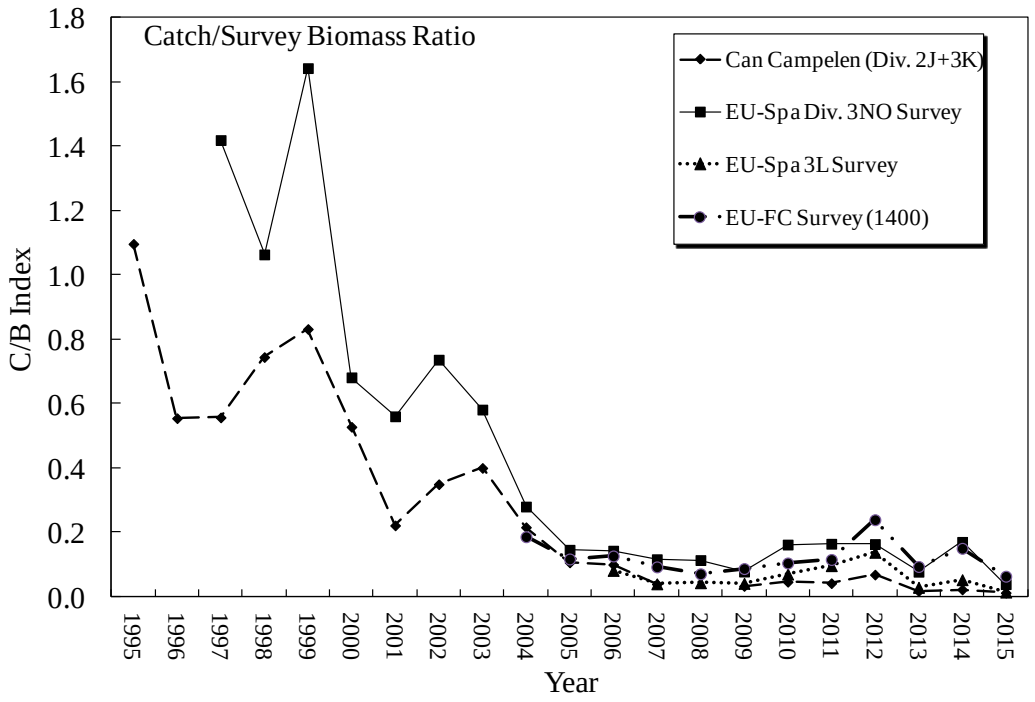

Fig. 16. The catch / biomass (C/B) indexes obtained using the Canadian fall survey (2J+3K), the EU Spanish 3NO, EU Spanish 3L and the EU Flemish Cap (till 1400 m) biomass indices in the period 1995-2012.

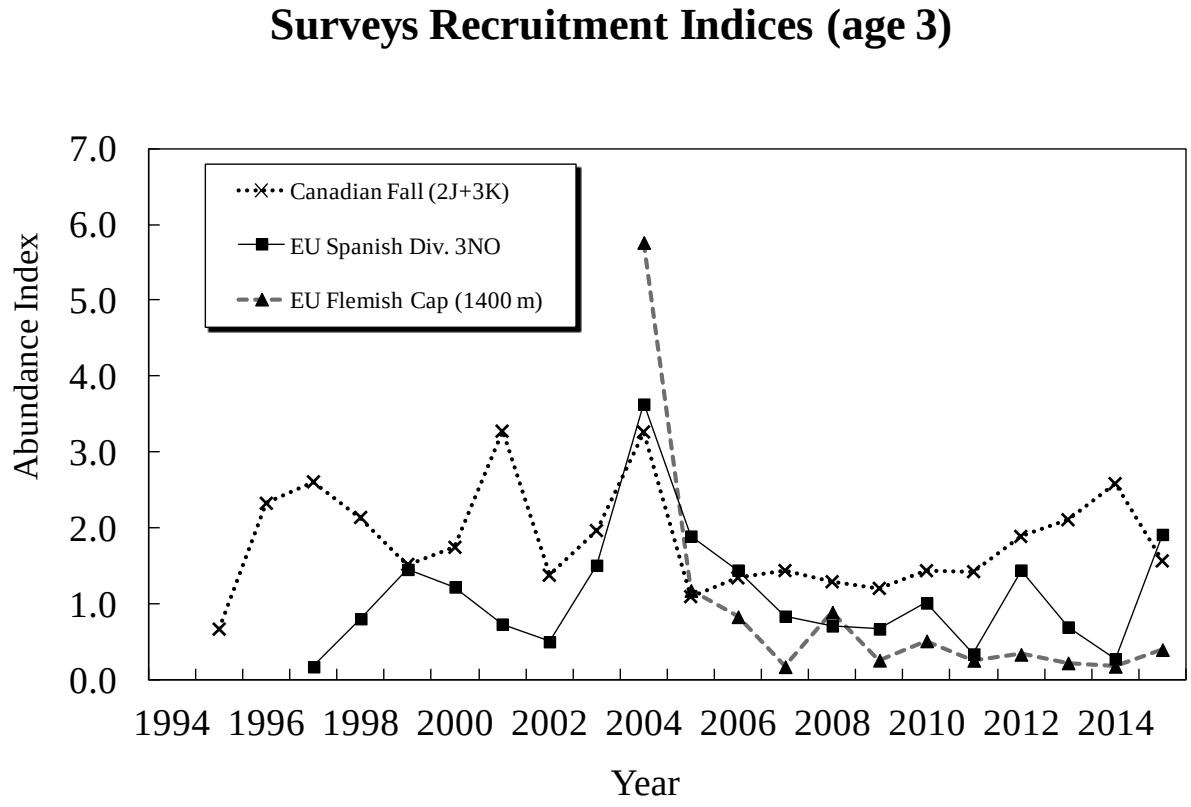

Fig. 17. Roughhead grenadier in Subareas 2+3: Canadian Fall (2J+3K), EU Spanish Div. 3NO survey and EU Flemish Cap (1400 m) survey abundance (MNPT) at ages 3.

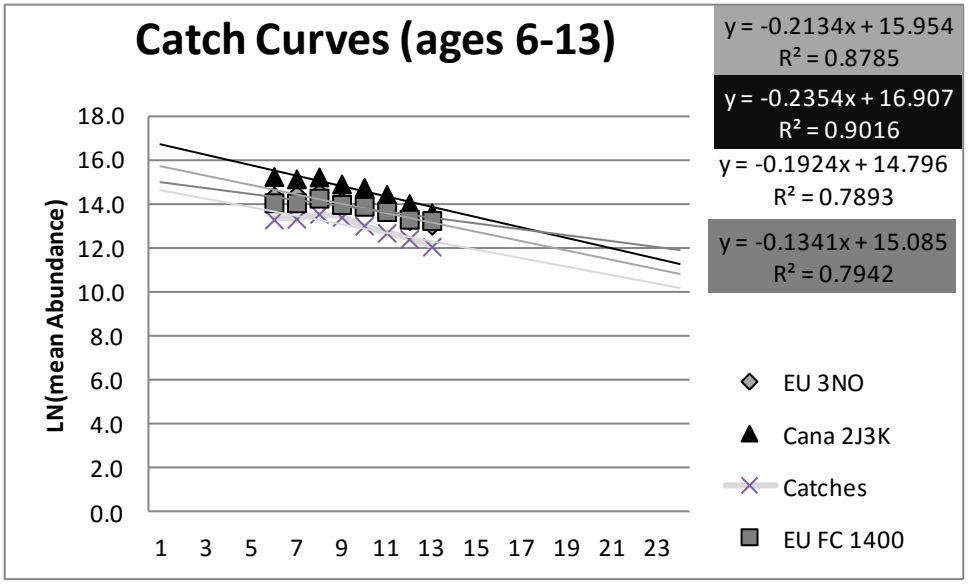

Fig. 18. Z values estimated from average catch curves for the most important ages in the catches (6-13) for commercial catches (1992-2015), Canadian Fall (2J+3K) (1996-2015) EU Spanish 3NO survey (1997-2015) and Flemish Cap survey till 1400 m (2004-2015).